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The use of *Urtica* sp. as a thermoregulatory device by Tephritid flies

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Abstract: In the montane tropical forest surrounding the Cuerici Biological Station, Costa Rica, the thorny herbaceous flower, *Urtica* sp., contains large numbers of small poikilothermic fruit flies (Tephritidae). We hypothesized that the tephritids use the greenhouse-like structure of the flower as a thermoregulatory device to raise their body temperatures. We recorded fly abundance, and temperatures over the course of one day in 34 flowers. Air temperature within flowers was greater than air temperatures outside of flowers at 09:00 and 11:00. As flowers warmed, flies within the flowers became increasingly active and many eventually left their flower. This happened earlier in the day in warm flowers than in cool flowers. Tephritid flies apparently exploit these flowers as part of a system of behavioral thermoregulation. This represents one avenue by which poikilothermic insects can survive and reproduce in an environment with such wide diel fluctuations in temperatures.

Key Words: Diptera, *fruit fly, insect, plant, symbiosis*

Introduction

Organisms exposed to extreme environmental conditions sometimes display unusual physiological or behavioral adaptations. In the montane tropical forest surrounding the Cuerici Biological Station, Cerro de la Muerte, Costa Rica, extreme diel variation in air temperatures creates an environment that is physiologically challenging for small poikilothermic organisms, such as fruit flies (Tephritidae). One species of tephritid can be found in large numbers within the flowers of *Urtica* sp., a thorny herbaceous member of the Urticaceae, which is patchily distributed in disturbed edge habitats. Preliminary observations indicated that fly abundance within flowers ranged from 0 to > 150 individuals, with the greatest abundance in the morning.

The montane environment at Cuerici experiences warm days (≈ 16° C) and cold nights (≈ 5° C). On most days, the coldest temperatures are well below the temperature at which insects such as tephritids can fly or even walk. Flowers of *Dahlia* sp. (Asteraceae), which have a parabolic shape similar to that of *Urtica* sp., have been shown to permit insects to warm themselves above ambient air temperature (Beadell et al. 1996). We hypothesized that tephritid flies use the *Urtica* sp. flowers in a similar way to raise their body temperature, and therefore their metabolism, at the beginning of each day when ambient temperature is low. We predicted that fly abundance would be highest during the cold morning hours, and that fly abundance would decrease when flower temperature could no longer increase their body temperatures.

Methods

We collected data on 29 - 30 January 2000 after previously selecting 34 individual flowers along the old road 20 m north of the Cuerici Biological Station, Cerro de la Muerte, Costa Rica. To experimentally increase flower temperature, we created foil reflectors by tying a trapezoid of aluminum foil (10 x 5 x 12 cm) below the flowers of 17 haphazardly selected individuals. We recorded fly abundance and air temperature both inside and outside flowers (Sensortek Bat 12 temperature probe) eight times during the day: 06:00 (just before sunrise), 07:00 (just after sunrise), 09:00, 11:00, 13:00, 15:00, 17:00 (just before sunset), and 18:00 (just after sunset). We also recorded fly abundance the following morning at 07:00, and compared this to the census at 07:00 the previous day using a paired t-test.

To determine if flowers are warming the microhabitat of flies in the morning, we used regression analyses to test relationships between: 1) flower and air temperature, 2) flower temperature in control and experimental flowers, and 3) flower temperature and fly abundance over the sample day.

Results

Average air temperatures inside flowers were greater than air temperatures outside flowers from 08:00 to 13:00 (highest at 09:00) but converged upon external air temperatures during the afternoon (Fig. 1). Flower temperatures did not differ between experimental and control flowers (Fig. 2), so these data were combined in subsequent analyses. Three flowers perished during the sample period and were excluded from analyses.

Fly abundance within flowers averaged ≈13 individuals/occupied flower until about 09:00 when flower temperatures reached their average maximum for the day at 16.6∞C (Fig. 3). The modest variability in fly abundance from 06:00 to 09:00 seemed to be due to miscounts from some flies being obscured from view. Fly abundance was not related to flower size (cm^3 of volume) ($r = 0.13$, $p = 0.17$). Average fly abundance within our study flowers declined from an average of 11.8 flies at 07:00 on 29 January to 3.3 flies at 07:00 on 30 January (mean difference ± SE = 9.4 ± 4.4, $t = 2.11$, $df = 29$, $p = 0.044$; total fly abundance in sample flowers = 379 vs. 98 on day 1 vs. day 2).

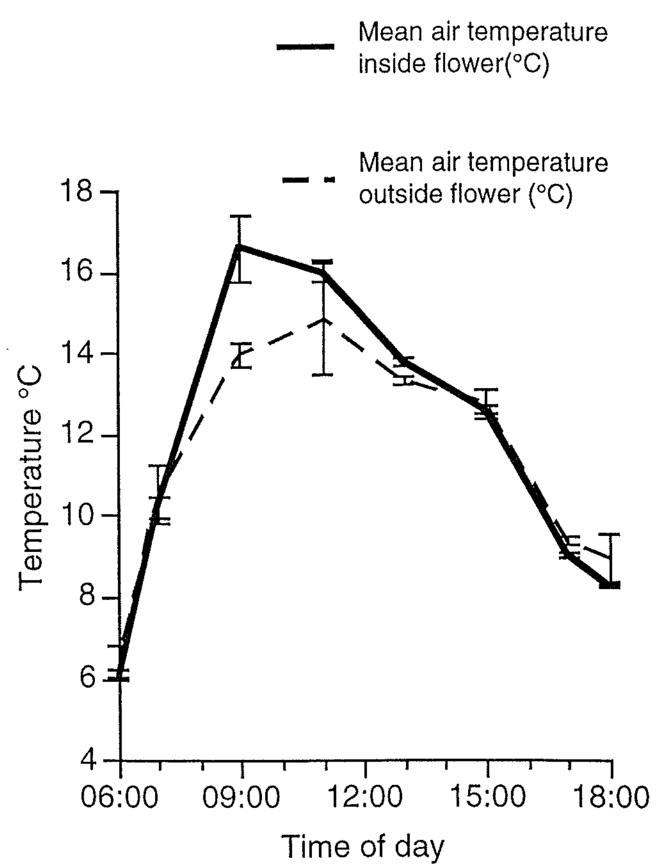

Figure 1. Comparison of average air temperature (± SE) inside and outside 34 flowers of *Urtica* sp. in the upper montane forests at Cuerici Biological Station, Costa Rica.

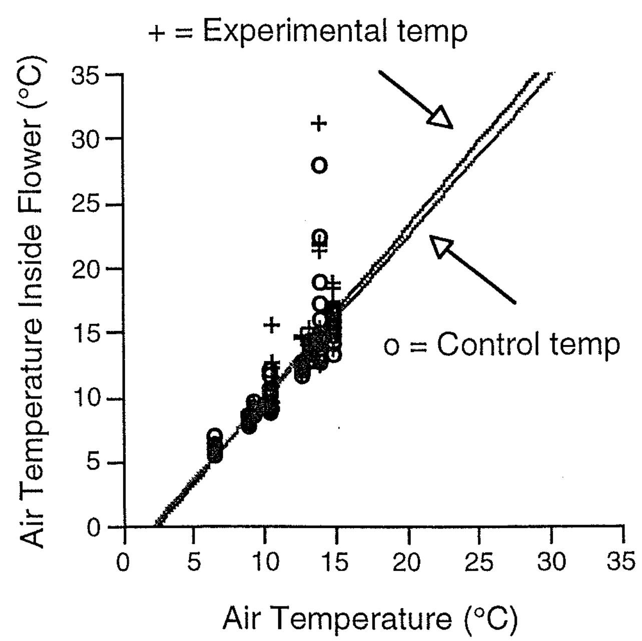

Figure 2. Air temperatures inside experimental and control flowers with respect to air temperatures outside of flowers (experimental = -2.62 + 1.25 • air temperature, $r^2 = 0.80$, $df = 1, 134$, $p < 0.001$; control = -3.2 + 1.32 • air temperature, $r^2 = 0.74$, $df = 1, 116$, $p < 0.001$). Flowers that were more than ≈2°C above outside air temperature were experiencing direct sunlight at the time of the measurement.

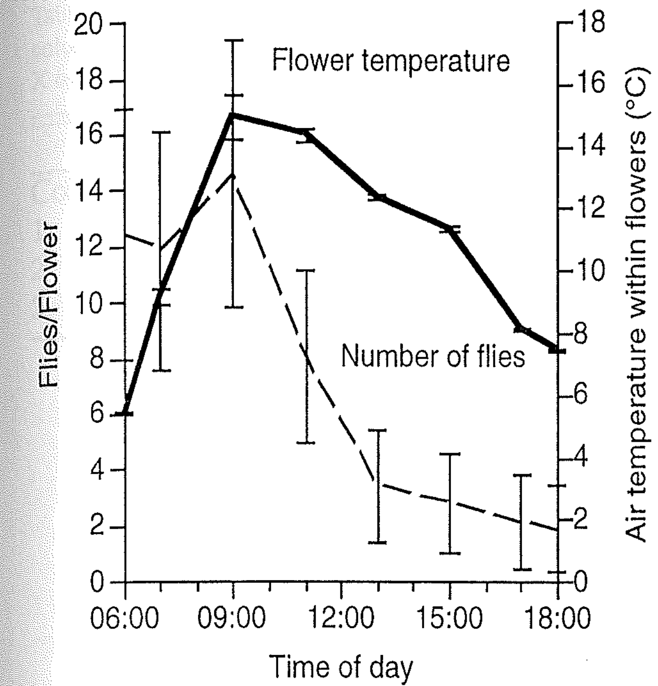

Figure 3. Mean number of flies within flowers of *Urtica* sp. (± SE) and mean air temperatures within flowers (± SE) between 06:00 and 18:00 on 29 January 2000.

Discussion

Air temperature inside of flowers rose more quickly and reached higher levels than air temperatures outside of flowers, indicating that small poikilotherms could exploit these flowers to elevate their body temperature in the mornings. We observed the highest abundance of flies when flower temperatures peaked at 09:00, suggesting that these flies spend the morning in flowers as a behavioral adaptation to counteract the adverse cold temperatures in this environment.

Flies tended to leave warm flowers earlier in the day than cool flowers (Fig. 3), which suggests that flies would benefit from choosing flowers that will warm most rapidly the next morning. Presumably, flies that become active relatively early in the day have a longer period of activity in which to mate and forage, but we do not know what the flies are doing when they are not in the flowers.

The number of flies in our study flowers decreased the morning following our sampling, probably because flies returning to the flower patch in the evening chose flowers other than those in our sample. *Urtica* sp. flowers seem to have a lifespan of ≈ 5-10 d (some of our study flowers had begun to wilt or had even dropped from the plant by the second day of our study). We hypothesized that many flies are returning to the patch of *Urtica* flowers each night and are preferentially occupying relatively young flowers.

In addition to the hypothesis that flies enjoy thermoregulatory benefits from the flower, there are at least three other possible explanations for the relationship between tephritid flies and the flowers of *Urtica* sp.: 1) the nectar is serving as a food source for these flies, as nectar does for some species of tephritids, 2) both males and females are present in the flower and use the flowers as a mating ground, and 3) *Urtica* sp. could be receiving benefits if, for example, flies aid in pollination or defense of the flower. Further studies are required to evaluate these possibilities. Nevertheless, this study suggests that the flies exploit these flowers as part of a system of behavioral thermoregulation. This illustrates one avenue by which poikilothermic insects can survive and reproduce in an environment with such wide diel fluctuations in temperatures, as are typical of tropical alpine environments.

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